Energy Technologies Area Lawrence Berkeley National Laboratory

Power Market Reform: Dividends, Market Impacts, and Transition Options

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Outline

- Background
- Research Questions
- Methods and Scenarios
- Results
- Sensitivity Analysis
- Conclusions

Background

- China is currently undergoing power sector reform
  - Change from planning to markets for both electricity pricing and dispatch

- Electricity market transition in China has the potential to further the country’s environmental and economic aspirations
  - Stop excess investment in coal power
  - Reduce curtailment of solar/wind/hydro
  - Meet air quality and GHG targets
  - Increase efficiency of power system operation

- Guangdong power market reform
  - Focusing on electricity wholesale market and promoting demand side management
  - Among the first batch of pilots to launch real-time wholesale market in 2018

- Market reforms in China have started to run into political economy obstacles
  - Current discussion in China lacks a more quantitative sense of what the impacts on different stakeholders might be, and how these could be overcome

Research questions

Overarching

- How can Guangdong (and China) best navigate the ***political economy*** of a transition to electricity markets?
- How can regulation and market design support the transition to a cleaner electricity system?

Specific

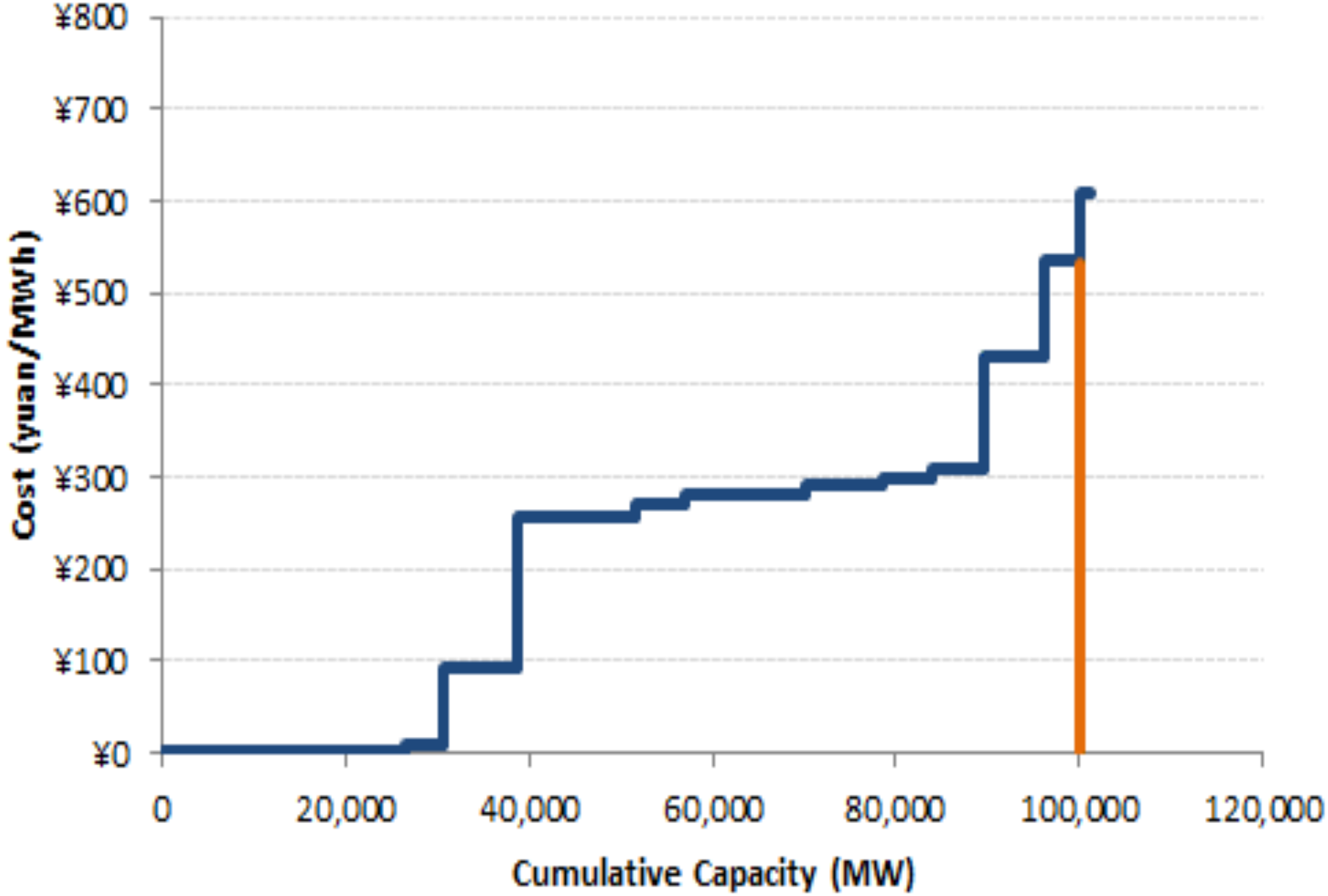
- How significant would the cost savings from market transition be, under different scenarios?
- How would markets affect consumers, different kinds of local generators, and importers?
- What might viable market transition strategies look like?

Approach

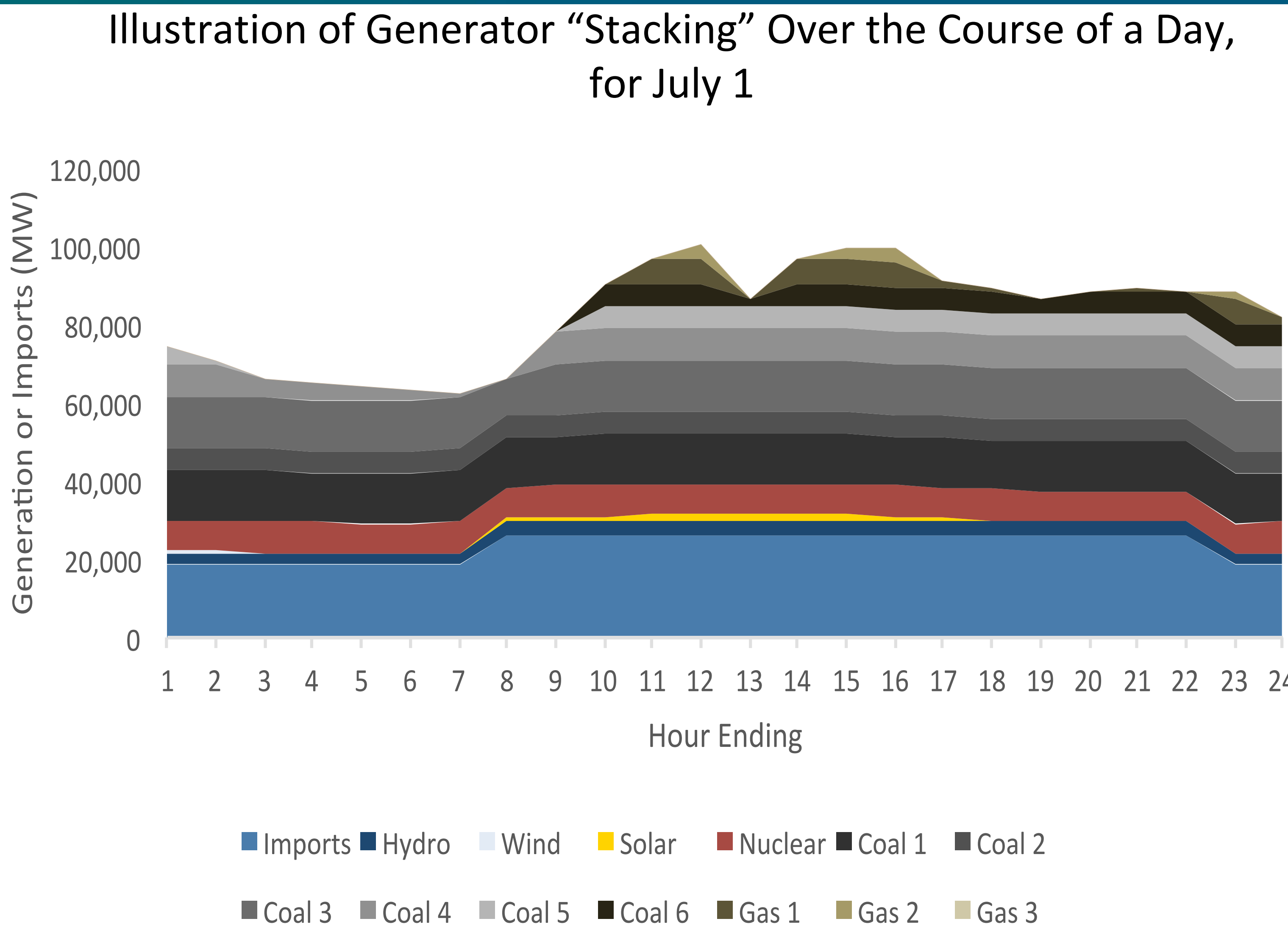
- Create relatively simple model of the Guangdong electricity system, focusing on structural differences between generators
- Assume convergence to economic (marginal cost-based) dispatch with a single market clearing price
- Examine total cost impacts relative to a reference scenario, impacts on net revenues for different types of generators

Market simulation– supply and demand for an hour

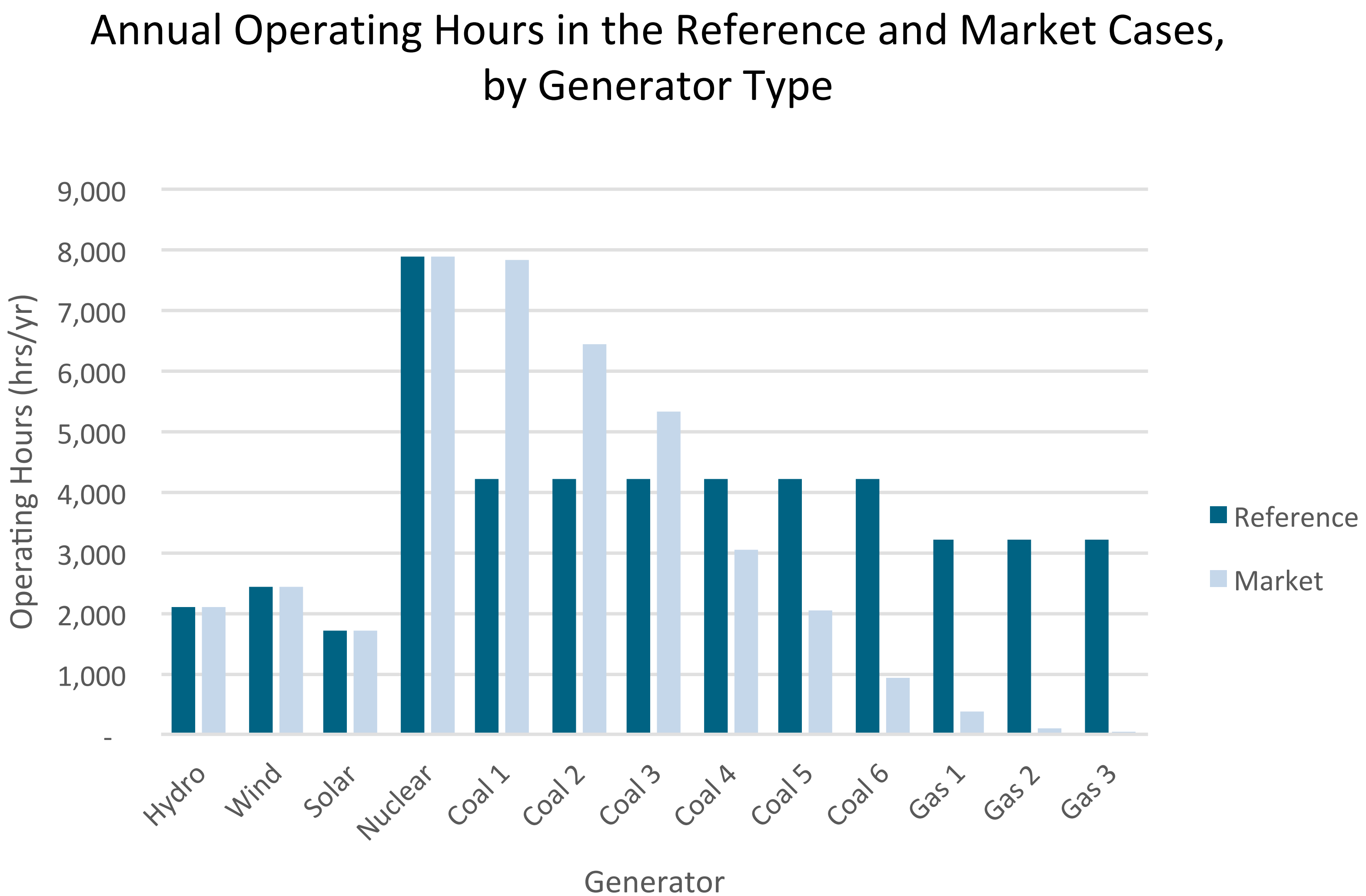
Supply-Demand Curve Illustration of Hourly Dispatch in the Stack Model, for Hour Ending 16:00 on July 1



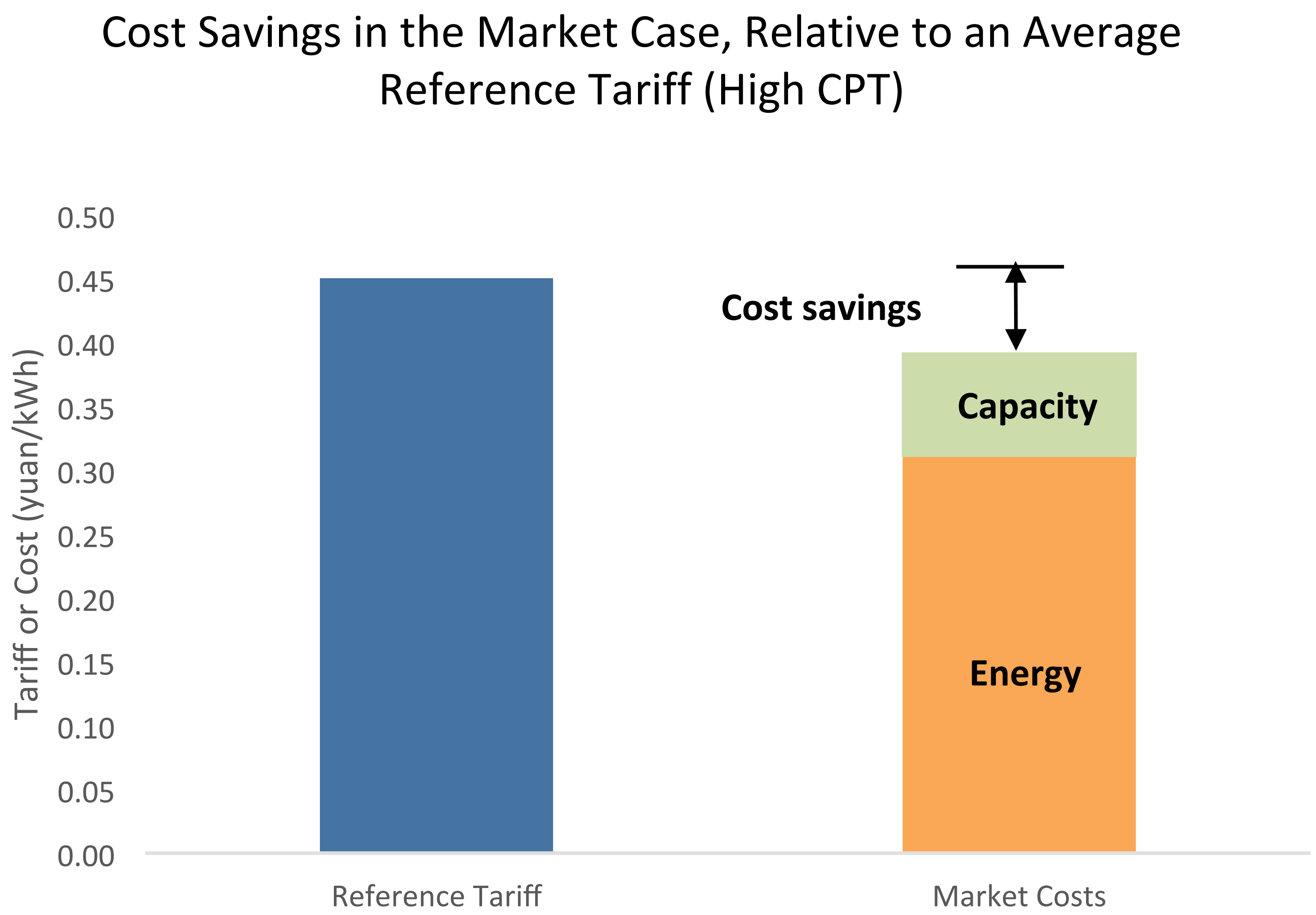
Market simulation– generator dispatch in one day



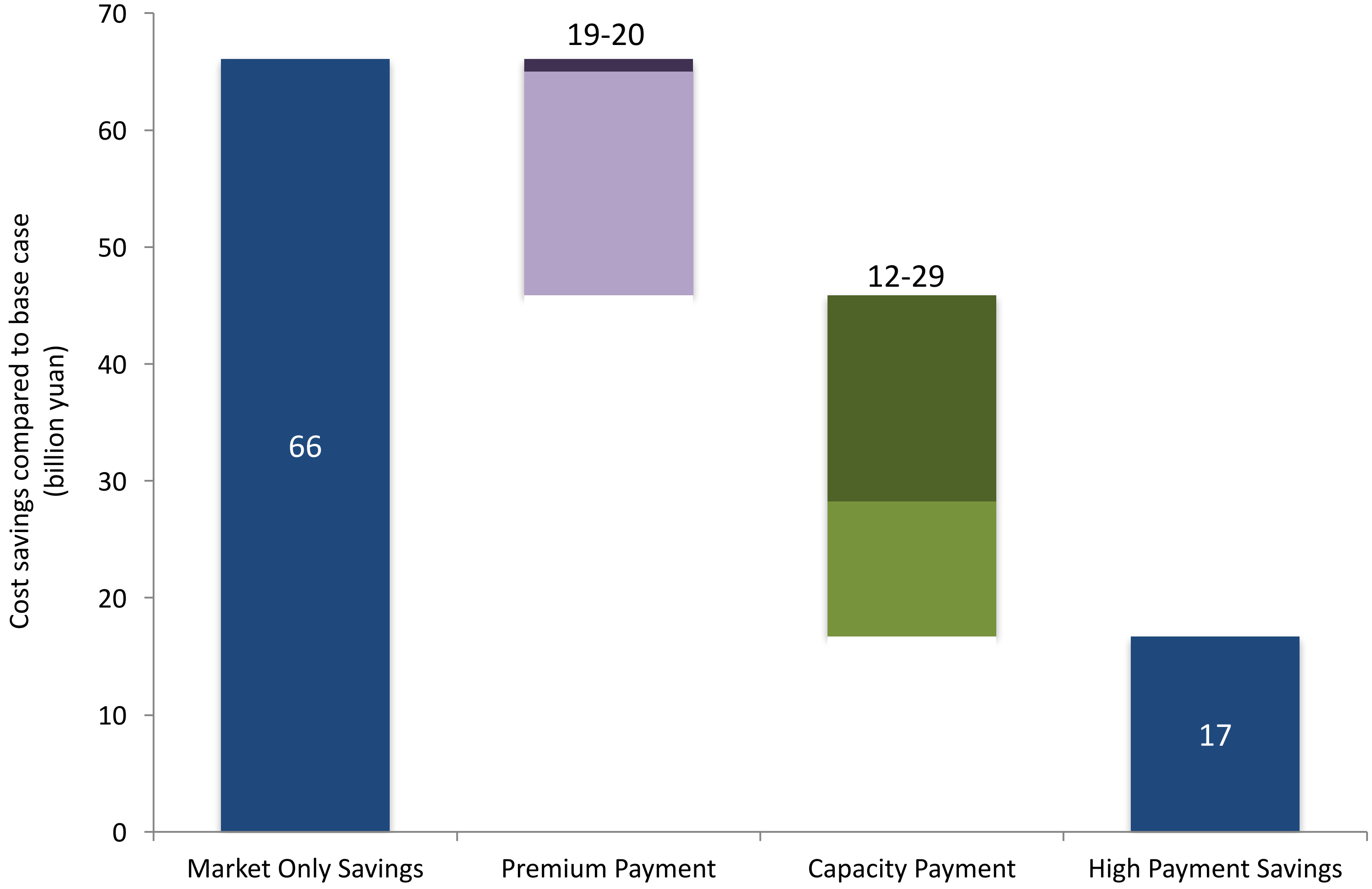
Impact of market transition on different type of generators



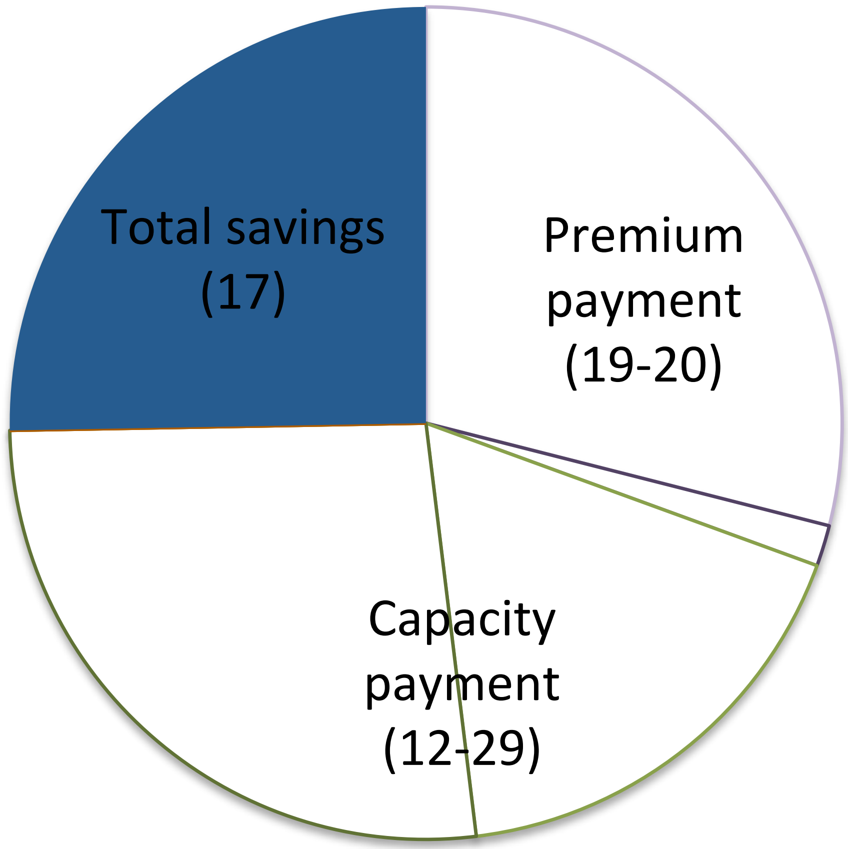
Results


Cost Savings in the Market Case, Relative to an Average Reference Tariff (High CPT)
Tariff or Cost (yuan/kWh)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Cost savings
Capacity
Energy
Reference Tariff
Market Costs

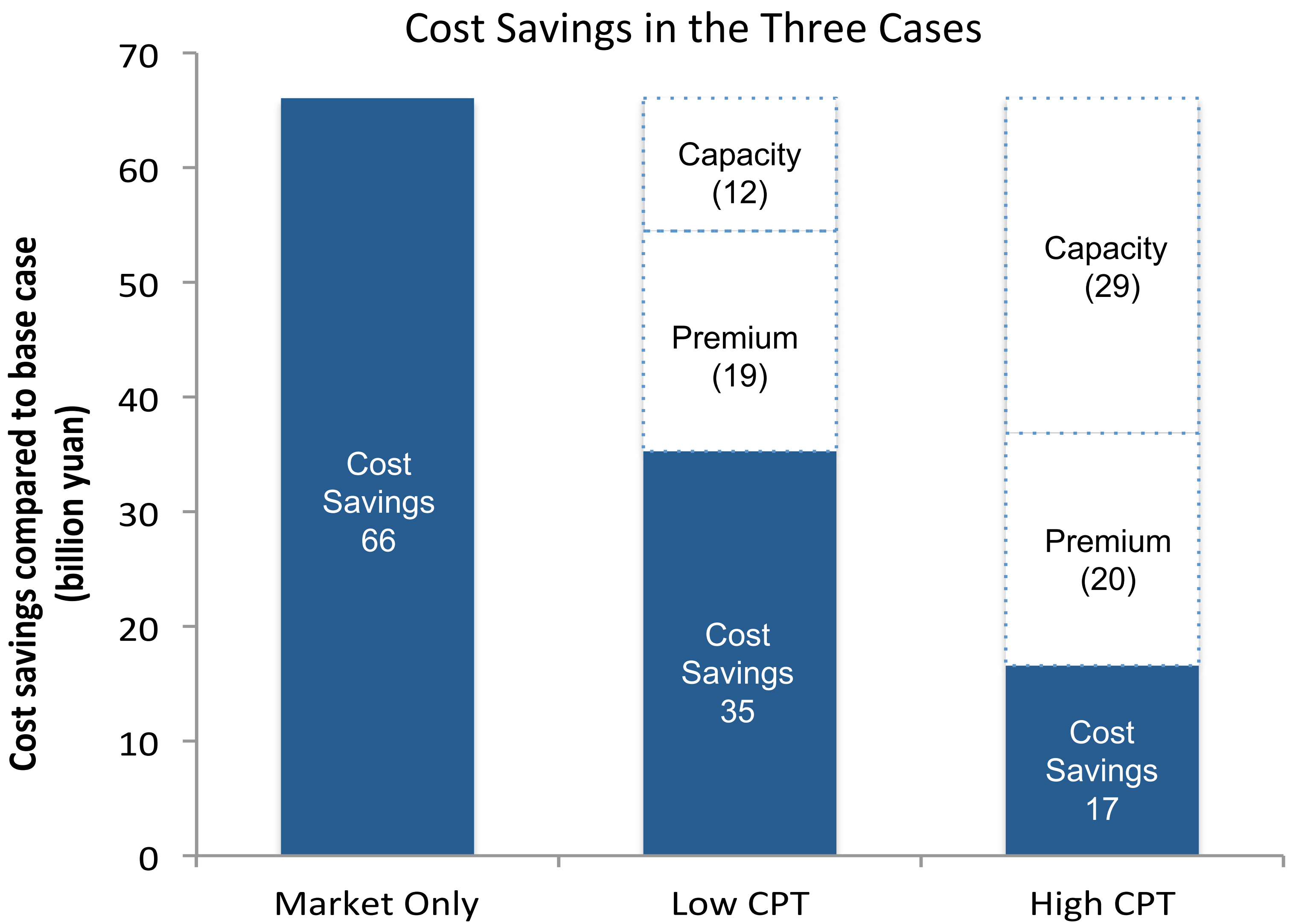
Transition towards market yield large cost savings (7-28%) for the society, but savings shrinks with additional payments



Transition towards market yield large cost savings for the society, but savings shrinks with additional payments



Transition towards market yield large cost savings for the society, but savings shrinks with additional payments



Sensitivity analysis – CO_2 prices

Results for Different CO_2 Price Levels*

		CO_2 Price			
	Unit	**0 yuan/tCO_2 (base)**	**50 yuan/tCO_2**	**100 yuan/tCO_2**	**500 yuan/tCO_2**
Total costs	Billion yuan	205	225	245	421
Production costs	Billion yuan	86	99	111	202
CO_2 emissions	Million tons CO_2	244	244	244	214

A CO_2 price of 50 to 100 yuan/tCO_2 increases total costs by 20 to 40 billion yuan but has no impact on merit order and thus does not reduce CO_2 emissions at all in the short run.

A 500 yuan/tCO_2 price leads to larger reductions in emissions but increases total costs by nearly a factor of two.

* Sensitivity analysis was based on the Low CPT scenario

Sensitivity analysis – net imports: reducing both emissions and costs

Results for Different Levels of Net Imports*

		Net Imports		
	Unit	30% (base)	35%	40%
Total costs	Billion yuan	205	199	194
Production costs	Billion yuan	86	78	70
CO_2 emissions	Million tons CO_2	244	220	195

* Sensitivity analysis was based on the Low CPT scenario

Conclusions – overarching conclusions

- Significant potential gains (RMB 17-66 Billion) from implementing electricity markets in Guangdong (and China)
  - The extent of these gains depends on how much in savings must be paid out as premiums to clean generation and paid to generators in the form of scarcity payments
  - Even with these payments, significant savings are likely to remain

- Factors influencing savings
  - The most important factor influencing savings is likely imports (of hydro from Yunnan), which has significant implications for market design
  - Fuel prices will also matter
  - CO_2 pricing is likely to be an expensive strategy for reducing CO_2 emissions in Guangdong in the short run

Conclusions – impacts on generators

- Key ways to address net revenue impacts on generators
  - Some form of side payment: politically and economically necessary
  - Need to think of how to enable demand-side resources to participate in providing reliability services

- Orienting these payments around a product, such as reliability (capacity), is likely to lead to lower overall costs

- Issues in the U.S. electricity industry over the past decade are likely to emerge in China
  - E.g. the financial viability of nuclear in markets, the role of demand response
  - For China, it would be salutary to head these issues off by anticipating them

Conclusions – forward looking

- The most important benefit of economic dispatch: Providing an overall economic framework for investments in generation, transmission, and demand-side resources (needs further analysis)

- Least-cost operation influences both the level and composition of generation investment, should serve to guide investment in transmission planning
  - Coal investment and generation: market prices are too low to support new investment in coal and gas generation
  - Hydro, wind, solar, and nuclear generation: likely continue to be policy driven, but market prices can shape both the level and composition of new investment (e.g., the balance between wind and solar generation).
  - Market prices play an important role in guiding new investments in storage

- U.S. experience: the largest long-term benefits of electricity market reform are in rationalizing investment costs

Thank You!

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Backup slides

Methods and scenarios

- Stack/Dispatch Model, Guangdong
- Four Scenarios
  - One Base Case
  - Three Market Cases

Scenario	Capacity payment	Premium payment
Market only **("Market Only")**	None	None
Low CPT payments **("Low CPT")**	100 yuan/kW-yr, paid to all qualifying generators	Difference between energy and capacity market revenues and current feed-in tariffs
High CPT payments **("High CPT")**	400 yuan/kW-yr, paid to all within-province thermal generators	Difference between energy and capacity market revenues and current feed-in tariffs

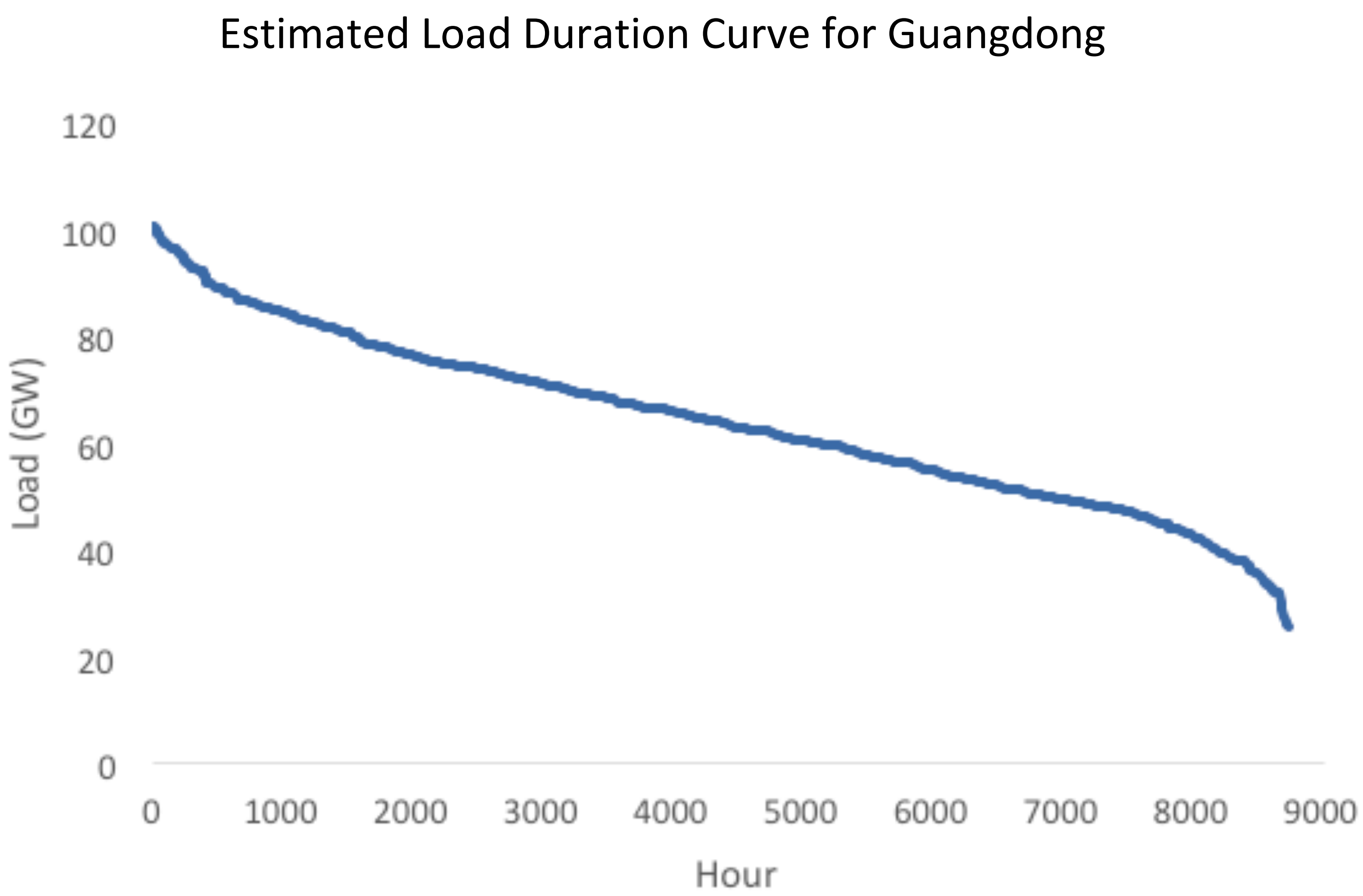
Base case

Demand: Total electricity consumption was 561TWh for Guangdong in 2015, about 30% of which were import electricity.

Supply: Installed capacity and base case annual operating hours by generation technology for within-province generation (table below)

Generation Technology	Installed Capacity (MW)	Annual Operating Hours (hours/yr)
Coal	59,511	4,237
Natural gas	13,438	3,200
Hydropower	9,104	2,096
Wind	3,633	2,438
Solar	2,369	1,717
Nuclear	8,862	7,884

Guangdong load duration curve



Sensitivity analysis – net imports, -20% emissions

Results for Different Levels of Net Imports*

		Net Imports		
	Unit	30% (base)	35%	40%
Total costs	Billion yuan	205	199	194
Production costs	Billion yuan	86	78	70
CO_2 emissions	Million tons CO_2	244	220	195

With the price-taker assumption for imports, increasing net imports reduces total costs, within-province production costs, and within-province CO_2 emissions.

Incremental expansion of imports displaces higher cost generation in Guangdong, but this effect saturates as imports continue to increase and higher cost generation has already been displaced.

Cost and emission reductions become more linear after import levels reach 40% and imports begin to displace medium-efficiency coal generation.

* Sensitivity analysis was based on the Low CPT scenario

Sensitivity analysis – fuel prices

Results for Different Coal Prices*

		Coal Price		
	Unit	700 yuan/tce	800 yuan/tce (base)	900 yuan/tce
Total costs	Billion yuan	191	205	219
Production costs	Billion yuan	78	86	95
Product cost savings	Billion yuan	12.7	12	11.2
CO_2 emissions	Million tons CO_2	244	244	244

Results for Different Natural Gas Prices*

		Natural Gas Price		
	Unit	1670 yuan/tce ($2.1\ yuan/m^3$)	1870 yuan/tce ($2.3\ yuan/m^3$) (base)	2070 yuan/tce ($2.5\ yuan/m^3$)
Total costs	Billion yuan	202	205	208
Production costs	Billion yuan	86	86	87
Product cost savings	Billion yuan	10.0	12.0	13.9
CO_2 emissions	Million tons CO_2	244	244	244

Higher/lower coal prices tend to reduce/increase market case benefits, as long as coal price changes are not incorporated into the benchmark tariff.

Higher coal prices have little impact on dispatch order in the market case.

Higher/lower natural gas prices similarly reduce/increase market case benefits, as long as coal price changes are not incorporated into the benchmark tariff.

Higher natural gas prices increase the benefits of coal to natural gas switching.

* Sensitivity analysis was based on the Low CPT scenario

Sensitivity analysis – CO_2 prices: expensive

Results for Different CO_2 Price Levels*

	Unit	CO_2 Price			
		0 yuan/tCO_2 (base)	50 yuan/tCO_2	100 yuan/tCO_2	500 yuan/tCO_2
Total costs	Billion yuan	205	225	245	421
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A 500 yuan/tCO_2 price leads to larger reductions in emissions but increases total costs by nearly a factor of two.

* Sensitivity analysis was based on the Low CPT scenario

Sensitivity analysis – wind and solar generation capacity

Results for Different Levels of Wind and Solar Installed Generation Capacity*

		Wind and Solar Installed Capacity		
	Unit	6,002 MW (base)	12,004 MW	18,006 MW
Total costs	Billion yuan	205	207	209
Production costs	Billion yuan	86	83	79
CO_2 emissions	Million tons CO_2	244	233	222

A doubling and tripling of wind and solar generation capacity lead to increases in total costs through higher premiums, and decreases in production costs and CO_2 emissions by displacing thermal generation.

* Sensitivity analysis was based on the Low CPT scenario

Sensitivity analysis – hydropower output

Results for Different Hydro Shapes and Hydro Operating Hours*

		Hydro Shape		Hydro Operating Hours	
	Unit	TOU block (base)	Load following	2,096 (base)	2,628
Total costs	Billion yuan	205	204	205	203
Production costs	Billion yuan	86	86	86	85
CO_2 emissions	Million tons CO_2	244	244	244	240

By allowing hydropower to follow load ("load following"), it reduces costs and emissions, but this effect is small.

Increasing hydropower operating hours to 2,628 (30% capacity factor) has a minimal impact on costs and emissions.

Both effects are small because within-province hydropower accounts for a small share (6% in the base case) of total generation.

* Sensitivity analysis was based on the Low CPT scenario

Net heat rates and installed capacity for each coal and each gas generator bin

Net Heat Rates and Installed Capacity for Each Coal Generator Bin

Category	Size (Capacity)	Vintage	Installed Capacity (MW)	Average Net Heat Rate (gce/kWh)
Coal 1	> 1,000 MW	All	14,264	281
Coal 2	600-1000 MW	2010-2017	6,840	301
Coal 3		1980-2009	15,424	315
Coal 4	300-600 MW	2000-2017	9,810	325
Coal 5		1980-1999	6,240	337
Coal 6	< 300 MW	All	6,933	350
Totals			**59,511**	**313**

Net Heat Rates and Installed Capacity for Each Gas Generator Bin

Category	Installed Capacity	Average Net Heat
Gas 1	7,391	220
Gas 2	4,703	275
Gas 3	1,344	315
Totals	**13,438**	**256**